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Effect of Plant Density of Hybrid Maize and Common Bean Varieties on the Productivity of Intercropping System at Jimma, South West Ethiopia

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Abstract

Limited farmland size owned by smallholding farmer is one of the challenges to increase crop production and productivity at the study area in particular and in the country at large. Accordingly, famers have a long standing traditional knowledge of growing multiple crop types in different cropping patterns. Intercropping is one of the crop combination systems practiced by resource poor farmers to increase crop production per unit area of land per year and reduce the risks to food and cash sources. However, research information is scanty on ideal intercropping technology options for irrigated agriculture. Hence, this study was conducted at the Jimma Agricultural Research Center in 2013/2014 with the objectives to determine the optimum component population density that maximizes productivity under Jimma conditions, southwest Ethiopia. The experiment was conducted in factorial experiment arranged in a Randomized Complete Block Design of three replications. The treatment combinations included six component densities (100% * 17.7%, 100% * 26.7%, 100% * 53.3%, 75% * 17.7%, 75% * 26.7%, 75% * 53.3%) of hybrid maize and common bean, and two common bean varieties (Nasir and Local Asendabo) along with sole maize and common bean varieties. Data on, phenology, growth, yield and yield components of the two crops were recorded and statistically analyzed. The analysis of variance showed that the interaction effects of bean varieties and component population densities as well as the main effects were comparable on the phenology of maize and common beans, except the main effects of varieties indicated significant variation on days to 50% emergency of common bean. All yield and yield components showed significant effect due to common bean variety, component density and interaction effects on maize and common bean. In general maize 100% population density intercropped with 26.7% population density of Nasir common bean variety; and as an alternative: - Maize with 75% population density intercropped with 53.3% population density of both varieties of common beans make farmers benefited from the system.

Key words: *Irrigation, Nasir, Local, Variety, Density*

1. Introduction

Suitable land area for food production through most parts of the world remains fixed and may even be decreasing, and it is becoming more important to raise crop productivity in order to meet the increasing food requirements of an increasing population all over the world (Midmore, 1993). Most of the developing nations lie in the tropical region and the population pressure is felt more acutely by these developing countries since the rate of population growth is higher and economic development is unable to keep pace with it (Palaniappan, 1985). Thus, the only way to increase agricultural production is to increase yield per unit area (Tamiru, 2013).

Maize (*Zea mays L.; Poacceae*) is the most important cereal after wheat and rice with regards to cultivation area in the world (Osagie, 1998). In Ethiopia, it is one of the major staple crops ranking first in yield potential per hectare and fourth in total area after teff (*Eragrostis tef*), barley and sorghum (IFPRI, 2010).

Common bean (*Phaseolus vulgaris L.*) is a major food legumes and ranks third most important worldwide food crop next to soybean and peanut (Singh, 1989). It is an important pulse crop distributed and grown in different parts of Ethiopia depending on climatic and socio-economic factors (Tenaw, 1990). It plays an important role in human nutrition and market economies of some rural and urban areas of the Ethiopia (CSA, 2009). Selection of appropriate cultivars, planting dates and plant densities are cultural practices that have been shown to affect common bean yield potential and stability (Norwood, 2001).

Intercropping is an old and commonly used agricultural cropping practice, of cultivating two or more crops in the same space at the same time (Carlson, 2008). Maize/legume intercropping has become one of the solutions for food security among small scale maize producers (Thobatsi, 2009). In most intercropping systems, growth and yield of legumes are usually suppressed by the dominant crop (Tamiru, 2013). The overall mixture densities and the relative proportion of component crops are important in determining yields and production efficiencies of cereal-legume intercrop systems (Zardari *et al.*, 2013).

The production obtained from maize in Jimma 2012/13 was 144,362.82ha with the total production of 454,755,428kg and productivity of 3,150kg/ha and the production obtained from common bean in 2012/13 was 4906.32ha with the total production of 4,428,590kg and productivity of 903 kg/ha (CSA, 2013). In this area, farmers land holding are very small. The average farmers land holding of maize and common bean is 0.33ha and 0.03ha, respectively (CSA, 2013). This acute land scarcity necessitates farmers to use other alternatives to improve their productivity.

The present study was therefore, initiated with the following specific objectives:

1. To determine the optimum component population density that maximizes productivity under Jimma conditions, southwest Ethiopia.

2. Materials and Methods

The experiment was conducted in South West Ethiopia during 2014 off season at Jimma Agricultural Research center, which is located at $7^0$40' latitude and 36^0 longitudes at an elevation of 1753 m.a.sl.

2.1. Treatments and Experimental Design

The treatments included six component densities (100% * 17.7%, 100% * 26.7%, 100% * 53.3%, 75% * 17.7%, 75% * 26.7%, 75% * 53.3%) of hybrid maize and common bean, and two common bean varieties (Nasir and Local Asendabo) accompanied with sole Maize and sole common bean varieties. The experiment was laid out in a factorial experiment arranged in Randomized Complete Block Design (RCBD) with three replications.

2.2. Agronomic Management

Planting of intercropped and sole cropped maize were carried out on (15/1/2014). At time of maize sowing, all plots received a basal application of ammonium phosphate (DAP, 18% N, 20% P) at the rate of 100 kg/ha. The intercropped maize stand was thinned to a population of 33,333 and 44,444 plants/ha with respect to its plant spacing within row spacing; and hoeing were taken place a week after emergence. And the sole maize was thinned to a density of 44,444 plants/ ha a week after emergence. The two common bean varieties (Nasir and local) were sown on (06/02/2014) with two seeds per hill on plots assigned for intercropping and sole common bean plots. The intercropped common bean varieties were drilled in between each two maize rows at 150 cm inter-row; and with intra-row spacing of 5 cm; 10 cm; 15 cm. The bean stand was then thinned to a population of 133,333; 66,666 and 44,444 plants/ ha a week after emergence, respectively. The sole common bean was hand sown with spacing of 40/10 cm and the stand was thinned to a density of 250,000 plants/ ha a week after emergence. The recommended phosphorous fertilizers were applied in the form of DAP at rate of 46 kg P_2O_5 ha^{-1} at planting for sole common bean plot. At knee height growth stage of maize, N in the form of urea (46% N) was applied at the rate of 50 kg ha^{-1}. After the crops attained full maturity stage, common bean and maize harvesting was done on 15/06/2014 and 16/06/2014 by hand at the grain moisture content of 12.5.

2.3. Maize Data Collection

Growth Phenology

Data on days to 50% tasseling, 50% silking and 50% maturity of maize were recorded when 50% of the plants in a plot reached their respective phenological stages.

Growth Parameters

Leaf area (cm^2): - was determined from the same five plants used for plant height per plot randomly as leaf length (L) x maximum leaf width (W) x 0.733 as described by McKee (1964)

Leaf area index (cm^2): - LAI were calculated as the ratio of total leaf area (cm^2) of the plant to the ground area coverage of maize.

Yield and Yield Components included

Number of cobs per plant: was counted from five randomly sampled plants per plot at the end of harvest in each plot. Numbers of kernels per cob: was taken from the same five randomly selected plants and from that, five cobs selected at the end of harvest in each plot and each of cobs kernels threshed and counted by seed counter.

Grain Yield (kg/ha): Grain yield were measured from the net plot area and expressed as kg/ha. Grain yield was adjusted to 12.5% moisture content using a digital moisture tester.

2.4. Response of Common Bean

Growth phenology:

Data on 50% crop emergence: - were counted from the date of sowing till when 50% seedling was emerged or two leafs were observed in each plot.

Data on 50% flowering: - were recorded when more than 50% of the plants produced flower in each plot by visual observation.

Data on 50% maturity: - were recorded from five randomly taken plants as the number of days from emergence to the date on which about 50 percent of the plants in a plot matured.

Growth Parameters

Plant height (cm): Plant height was recorded as the height of plant grown from the ground level from five randomly sampled plants at the end of 50% flowering in each plot.

Leaf area: -were measured from the same five plants already earmarked for recording plant height using leaf area meter at the end of 50% flowering stage by distractive approach.

Leaf area index: - Were determined by measuring five plants canopy in each plot and dividing leaf area by their canopy.

Yield and Yield Components

Number of pods per plant: - Number of pods was counted from the same five randomly selected plants at the end of harvest in each plot.

Number of seeds per pod: - Was taken from the same five randomly selected pods at the end of harvest and each of seeds were counted manually in each plot.

Grain Yield (kg/ha): Bean yields were measured from the net plot area and expressed as kg/ha. Bean yield was adjusted to 12% moisture using a digital moisture tester.

2.5. Land Productivity

Productivity of the intercropping system was determined by calculating the land equivalent ratio (LER) as per (Willey 1991).

$$\mathbf{LER} = \text{La} + \text{Lb} = \frac{Ya}{Sa} + \frac{Yb}{Sb},$$

Where, La and Lb = the LERs for maize and common bean crops in the mixture respectively; and Ya and Yb = the maize and common bean crop yields in an intercropping situations, Sa and Sb= the yield of maize and common bean in sole crops.

2.6. Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using (Gen Stat version 13). Significance differences between treatment means were delineated using Least Significance Difference (LSD) test at 5% probability level.

3. Results and Discussion

3.1. Response of Maize

3.1. 2. Phenology and Growth Response

The analysis of variance showed that days to 50% tasseling, days to 50% silking and days to 50% maturity were not significantly (Appendix Table1) influenced by the main effect of common bean variety. Likewise, the component density and the cropping system effects were observed to be non-considerable for all phenological parameters of maize in the study. It might be from the environmental factors that did not cause influence on phenology of maize; because the experimental location of the plant was the same for all and it did not cause variation on maize phenology. Similar to this finding, Demessew (2002); Yesuf (2003) and Dechasa (2005) reported that days to 50% emergence and maturity of maize/common bean and sorghum/common bean are not affected by component planting density.

The main effect of common bean varieties, component planting density as well as cropping system had no significant effect on the days to 50% physiological maturity of maize (Appendix Table1). The mean number of days required from planting to maturity was (121) days for both sole and intercropped maize (Table 1). Since maize as a main crop was not influenced by significance different on maize maturity time, indicating the more effect of genetic factors, because the variety of maize did not showed difference as it is only the same variety for all treatments. The result agreed with the findings of Demessew (2002); Yesuf, (2003); Sisay (2004) whose described that non-significant effect of cropping system was reported on physiological maturity of maize. Similarly, Wahan (1983) in Abraha (2013) mentioned that maize mono crop has growth period of 120 days and was not significantly different from maize intercropped with cowpea cultivars Glenda and Agrinaw which took 120 and 121 days to maturity.

Table 1. The main effects of common bean variety and component density on phenology and plant height of hybrid maize intercrop and sole crop at Jimma

Treatment	Days to 50%			
	Tasseling	Silking	Maturity	Plant height (cm)
M+N	75.89	81.17	120.78	237.12
M+L	75.78	81.06	120.61	238.10
SEM (±)	0.28	0.22	0.21	1.55
LSD ($_{0.05}$)	NS	NS	NS	NS
Maize and Common bean Component density				
M+C (100% *17.7%)	75.33	80.68	120.2	236.5
M+C (100% * 26.7%)	75.33	80.83	120.5	234.3
M+C (100% * 53.3%)	75.67	81.02	120.5	237.0
M+C (75% * 17.7%)	76.00	81.18	120.7	239.4
M+C (75% * 26.7%)	76.00	81.18	120.5	241.2
M+C (75% * 53.3%)	76.67	81.83	121.8	237.3
SEM (±)	0.50	0.38	0.37	1.55
LSD ($_{0.05}$)	NS	NS	NS	NS
Cv (%)	1.6	1.2	0.7	5.45
Cropping pattern				
Inter cropped maize	75.84	81.12	120.71	236
Sole Maize	76.00	81.33	121	235.7
SEM (±)	0.37	0.85	0.66	2.13
LSD ($_{0.05}$)	NS	NS	NS	NS
CV (%)	1.6	1.1	0.8	4.3

LSD=Least Significant Difference, CV=Coefficient of Variation, SEM = Standard Error of Mean, M = maize, N = Nasir, C=common bean, M + N =Maize + Nasir, M + L=Maize + Local Asendabo.

3.1. 3. Growth Response

Leaf area: Results showed that total leaf area of maize was significantly ($P < 0.01$) affected by the main effect of common bean variety, component density and interaction of common bean variety and component density of the common bean and maize; however cropping system showed non-significant variation (Appendix Table 1). The highest leaf area (546.8 cm^2) was recorded by the interaction effect of 75% population density of maize and 17.7% local bean population density. In contrast, the lowest (444.8 cm^2) was recorded by the interaction effect of 100% population density of maize and 53.3% local common bean variety population density (Table 2). The reduction in leaf area of maize could be due to the enhanced local bean plant height and reduce leaf growth of maize with increased population density of bean from low light interception during the latter growth stages. Moreover, the time at which local common bean growth and cover the maize was the critical period at which light must be harvested by crops and greater assimilate must be supplied by the leaf in order to increase yield. In another study, Tsubo *et al.* (2003) on maize/bean intercropping reported that the photosynthetic organ (leaves) of maize becomes thinner and reduced its area due to shading effect of common bean.

Leaf area index: As indicated in (Appendix Table 1), leaf area index was significantly ($P<0.05$) affected by the interaction effect of component population density and common bean variety. The maximum leaf area index of maize 4.06 was recorded by 100% maize population density in combination with 53.3% Nasir population density. In contrast, the minimum (1.70) was recorded when 100% maize population density mixed with 53.3% local common bean variety population density (Table 3). However non-significant variation was recorded between cropping system, the results depicted that intercropped maize has lower LAI than sole maize (Table 3). The decrease in LAI in the intercropped maize could be most likely due to inter specific competitions among the higher population of the component crops for growth resources. Also the nature of local variety to climb nearby crop and canopy structures due to its larger leaf might be decrease the other crops LAI. Similarly, Pal (2004) reported that optimum LAI in crop communities is attained with adjustment of plant density and leaf area per plant. And the leaf area index per plant remained constant or unaffected until plant stand is increased above the density at which neighboring plants begin to compete for the resources. On the contrary, Tamado (1994); Sisay (2004) reported that planting pattern and plant density or their interaction on leaf area indices of sorghum was not statistically significant. In growing canopies, foliar traits (such as leaf area index and leaf mass per unit area) are the important factors in leaf light harvesting capacity and photosynthetic potentials Niinemets and Sack (2006).

Table 2. Interaction effect of common bean variety and component density of maize and common bean on leaf area (cm^2) of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	462.2^{f}	496^{de}	511.0^{c}
Maize 100% + Nasir	508.1^{c}	530.1^{b}	488.6^{e}
Maize 75% + Local	546.8^{a}	496.0^{de}	471.1^{f}
Maize 100%+ Local	508.1^{c}	505.4^{cd}	444.8^{g}
SEM (±)	5.02		
LSD $_{(0.05)}$	10.41		
CV (%)	4.2		
Intercrop Vs Sole crop			
Inter crop	497.47		
Sole crop	504.40		
SEM (±)	3.45		
LSD $_{(0.05)}$	NS		
CV (%)	3.9		

Means followed by the same letter within a column are not significantly different from each Other at 5 % level of significance. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation

Table 3. Interaction effect of common bean variety and component density of maize and common bean on Leaf Area Index of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	3.48ab	3.48^{ab}	3.09^{ab}
Maize 100% + Nasir	3.23^{c}	4.04^{a}	4.06^{a}
Maize 75% + Local	3.98^{b}	3.93^{b}	3.07^{ab}
Maize 100%+ Local	4.00^{a}	3.47^{c}	1.70^{b}
SEM (±)	0.95		
LSD $_{(0.05)}$	0.46		
CV (%)	21.6		
Intercropped vs sole cropped			
Inter crop	3.46		
Sole crop	3.78		
SEM (±)	0.61		
LSD $_{(0.05)}$	NS		
CV (%)	9.3		

Means followed by the same letter within a column are not significantly different from each Other at 5 % level of significance. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

3.1.4. Yield and Yield Components

3.1.4.1. Yield Components

Number of cobs per plant: The analysis of variance (Appendix Table 1) indicated that, however cropping system indicates non-significant effect, the main effect of variety, component population density and the interaction effect of them had highly significant effect ($P<0.01$) on number of cobs per plant. Accordingly, the highest cob number was recorded from 100% maize population density intercropped with 26.7% population density of Nasir common bean variety. The lowest cob number per plant was recorded from 100% maize population density intercropped with 53.3% Local bean population density (Table 4). The highest cob number might be from the low competition of crops caused from optimum combined population density of maize and common bean crops. Because high plant density might reduce light interception per plant and it is likely that mutual shading affect source capacity to supply a second ear with photo assimilate. Thus, apical-ear yield seemed to be sink-limited, while source capacity seemed to limit the growth of the second ear. Edmeades *et al*. (2000) demonstrated that assimilates moved preferentially from a leaf to its nearest sink. This implies that leaves above and immediately below the primary ear supply most of assimilate for grain filling, while assimilates from the lower leaves are more likely to be translocate into the root and lower stem.

Table4. Interaction effect of common bean variety and component density of maize and common bean on number of cobs per plant of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	1.95[b]	1.45[f]	1.64[d]
Maize 100% + Nasir	1.42[f]	2.19[a]	1.72[c]
Maize 75% + Local	1.75[c]	1.13[g]	1.65[d]
Maize 100%+ Local	1.42[f]	1.56[e]	1.00[h]
SEM (±)	0.03		
LSD $_{(0.05)}$	0.05		
CV (%)	2.00		
Intercropped vs sole cropped			
Inter crop	1.57		
Sole crop	1.51		
SEM (±)	0.02		
LSD $_{(0.05)}$	NS		
CV (%)	5.90		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

Number of seeds per cob: Results showed that number of kernels (seed) per cob was highly significantly affected by the main effects of variety and component population density and by the interaction effects of the main effects, but cropping system did not showed significant effect. The maximum number of kernel (557.3) per cob was recorded by 100% maize population density mixed with 26.7% Nasir variety population density and the minimum (190.8) seeds per cob was recorded by 100% maize population mixed with 53.3% Local common bean population density (Table 5). The maximum seed number might be also from the low competition of crops and the lowest caused from the high competition of crops for nutrient and moisture that leads to decrease in fertile plants to bear high seeds. Buren *et al*. (1994) reported that the number of plants at low or high plant density becomes a limiting factor for the yield of maize crops. At low plant density the number of plants limit yield because of few cobs produced, whereas at high plant density yield is limited by the number of barren plants and a decrease in number of kernels per ear or both (Hashemi-Dezfouli and Herbert, 1992).

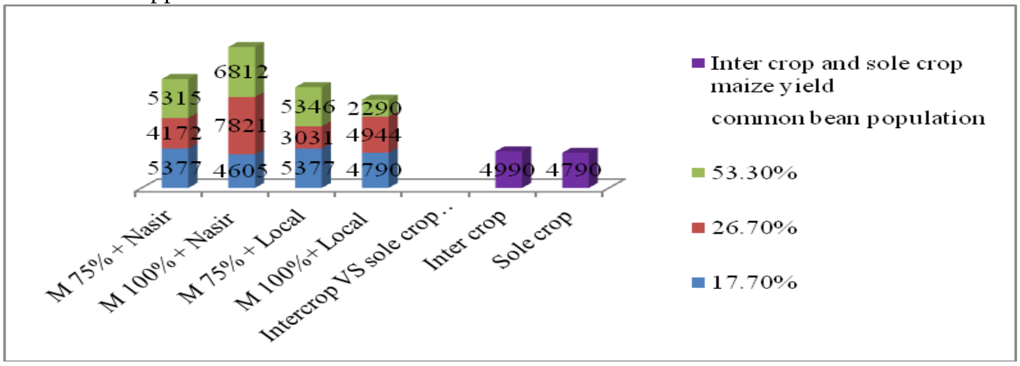
Table5. Interaction effect of common bean variety and component density of maize and common bean on number of seeds per cob of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	471.1[c]	332.5[i]	549.4[b]
Maize 100% + Nasir	337.6[i]	557.3[a]	453.3[d]
Maize 75% + Local	414.7[e]	204.9[j]	407.3[f]
Maize 100%+ Local	356.1[h]	389.1[g]	190.8[k]
SEM (±)	0.03		
LSD $_{(0.05)}$	5.28		
CV (%)	2.10		
Intercropped vs Sole cropped			
Inter crop	388.68		
Sole crop	375.80		
SEM (±)	0.02		
LSD $_{(0.05)}$	NS		
CV (%)	5.89		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significance. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

Grain yield: The result regarding grain yield showed that there were highly significant ($P<0.01$) differences in grain yield of maize due to the main effect of variety and component population density as well as interaction effect (Appendix Table 1). Among intercropping the maximum grain yield (7821 kg/ha) was recorded by the interaction of 100% maize population density intercropped with 26.7% Nasir common bean population density. The minimum grain yield (2290 kg/ha) was recorded by 100% maize population density intercropped with 53.3% local common bean population density (Figure 1). This showed that among population density of maize and common bean, 100% maize population density and 26.7% Nasir common bean population density gave the maximum grain yield and the other yield components revealed the same result. This was as a result of population density was the optimum that do not allow competition among crop for nutrient and the wide row spacing with uneven density, which seems favorable for light interception in the middle and lower canopies; also the Nasir Variety which was intercropped with maize was not computed with maize for nutrient and light. Moreover it increases nitrogen fertilizer by nodules for maize. In agreement with this, Tesfa *et al*. (2002) found the highest grain yield, when the optimum total plant density was higher than that of either sole crop.

Figure 1.Interaction effect of common bean variety and component density of maize and common bean on yield per hectare of sole and intercropped maize.



Interaction of variety and component density
SEM (±) = 71.78
LSD (0.05) = 124.3
CV (%) = 16.57

Intercrop Vs. sole crop
SEM (±) = 203.78
LSD (0.05) = 293.52
CV = 18.44

MY= Maize Yield, SEM= Standard Error of Mean, LSD = Least Significance Difference, CV = Coefficient of variation.

3.2. Common Bean Response

3.2.1. Crop phenology

The analysis of variance (Appendix Table 2) showed that days to 50% flowering and days to 50% maturity unlike that of days to 50% emergency were not significantly affected by the main effect of common bean variety. Similarly, population density and cropping system effects as well as interaction effect were not significantly observed for all phonological parameters of common bean in the study (Table6). Days to 50% emergency was significantly affected by the main effect of variety. The average days to 50% emergency of intercropped local bean was 9.43 and the average days to 50% emergency of intercropped Nasir were 8.02 days. The early emergency of Nasir variety might be from the nature of variety, because different varieties have their own emergency period.

Table 6. The main effect of component density and common bean variety on phenology of common bean sole and intercropped with maize.

Source of Variation	days to 50% emergency	days to 50% flowering	days to 50% maturity
Common bean Variety			
M+N	8.20	52.06	90.44
M+L	9.43	51.78	90.94
SEM (±)	0.11	0.22	0.27
LSD ($_{0.05}$)	0.31	NS	NS
Maize and Common bean Component density M+C (100% * 17.7%)	8.85	52.00	90.17
M+C (100% * 26.7%)	8.63	51.83	90.67
M+C (100% * 53.3%)	8.50	51.83	90.83
M+C (75% * 17.7%)	9.12	51.83	90.83
M+C (75% * 26.7%)	8.95	52.00	91.17
M+C (75% * 53.3%)	8.85	52.00	90.50
SEM (±)	0.18	0.39	0.460
LSD ($_{0.05}$)	NS	NS	NS
Cv (%)	5.0	1.8	1.2
Inter crop Vs Sole cropped			
Inter crop	8.82	51.92	90.70
Sole L	9.53	52.33	90.00
Sole N	8.13	52.00	90.67
SEM (±)	0.37	0.79	0.97
LSD ($_{0.05}$)	NS	NS	NS
Cv (%)	5.1	3.9	1.3

M = maize, N = Nasir, C= common bean, M + N =Maize + Nasir, M + L=Maize + Local Asendabo, SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

3.2.2. Growth Parameters

Plant height: As indicated in (Appendix Table 2), the main effect of variety, component population density and the interaction effect of component density and variety had significant (P<0.05) effect on plant height of common bean. The maximum plant height 186.3 cm was recorded by 26.7% local common bean population density intercropped with 75% maize population density. The minimum plant height (92.3 cm) was recorded by 75% maize population density intercropped with 17.7% Nasir common bean population density (Table 7). The difference in plant height of the varieties could be attributed to the difference in their genetic makeup and due to the population density of combined crops. In agreement with this, Shahzad *et al*. (2007) reported that, height of the crop is mainly controlled by the genetic makeup of a genotype and it can also be affected by the environmental factors. The result obtained from this study was agreed with Tilahun (2002), who reported plant height was significantly affected by planting arrangement and the interaction of planting density and plant arrangement but not due to the main effect of plant densities.

Leaf area: The main effect of variety and population density showed significant ($P<0.01$) in affecting the leaf area. Likewise interaction effect and cropping system showed a significant variation in leaf area. The maximum (436.8 cm^2) leaf area was recorded by 17.7% population density of local bean intercropped with 100% maize population densities and the minimum (214.5 cm^2) were recorded when 53.3% Nasir common bean variety intercropped with 100% maize population density (Table 8). As indicated in the result the lower leaf area was observed in the higher population density that might be resulted from interspecific competition between plants, and the lower population density results higher leaf area.

Leaf area index: The result evidenced that, the main effect of component density and variety as well as their interaction had significant ($P<0.01$) effect on leaf area index (Appendix Table 2). The maximum 4.66 leaf area index was recorded by 53.3% Nasir common bean population density intercropped with 75% maize population density. The lowest 1.48 was recorded by 53.3% Nasir common bean population density intercropped with 100% maize population density (Table 9). This showed that, as the maize population density intercropped with common bean increase in population density the leaf area index decrease; because it might be influenced by the high competition of the component crops that leads to decrease the in photosynthetic capacity of the crops. Similarly Demesew (2002) obtained a significant variation on leaf area index of haricot bean intercropped with maize. Moreover, Tilahun (2002) indicated that the main effects of both plant density of faba bean and planting arrangement had a significant effect on LAI of the faba bean intercropped with maize.

Table71. Interaction effect of common bean variety and component density of maize and common bean on Plant Height of sole and intercropped common bean

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	92.3^{d}	124.5^{c}	121.4^{c}
Maize 100% + Nasir	148.3^{bc}	138.3^{c}	130.2^{c}
Maize 75% + Local	182.5^{a}	186.3^{a}	180.5^{a}
Maize 100%+ Local	176.2^{a}	176.5^{a}	171.9^{ab}
SEM (±)	5.56		
LSD $_{(0.05)}$	11.16		
CV (%)	10.5		
Intercropped vs Sole cropped			
Inter crop	152.41		
Sole crop	155.00		
SEM (±)	25.98		
LSD $_{(0.05)}$	NS		
CV (%)	10.10		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Table8. Interaction effect of common bean variety and component density of maize and common bean on Leaf Area of sole and intercropped common bean.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	231.7^{gh}	239.5^{g}	274.2^{d}
Maize 100% + Nasir	304.3^{de}	421.8^{a}	214.5^{h}
Maize 75% + Local	324.7^{cd}	298.9^{e}	367.5^{b}
Maize 100%+ Local	436.8^{a}	331.5^{c}	330.3^{c}
SEM (±)	1.283		
LSD $_{(0.05)}$	2.66		
CV (%)	4.40		
Intercropped vs Sole cropped			
Inter crop	314.64^{a}		
Sole crop	273.00^{b}		
SEM (±)	9.96		
LSD $_{(0.05)}$	20.47		
CV (%)	3.00		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Table9. Interaction effect of common bean variety and component density of maize and common bean on Leaf Area Index of sole and intercropped common bean

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	2.60^{cd}	3.13^{bc}	4.66^{a}
Maize 100% + Nasir	3.23^{bc}	2.75^{cde}	1.48^{e}
Maize 75% + Local	2.60^{cd}	2.94^{bc}	3.14^{bc}
Maize 100%+ Local	4.50^{a}	1.79^{de}	1.64^{cd}
SEM (±)	0.37		
LSD $_{(0.05)}$	1.07		
CV (%)	12.6		
Intercropped vs Sole cropped			
Inter crop	2.87		
Sole crop	3.04		
SEM (±)	0.37		
LSD $_{(0.05)}$	NS		
CV (%)	13.3		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

3.2.3 Yield Components and Grain Yield

3.2.3.1. Yield Components

Number of pods per plant: Analysis of variance showed that, cropping system and the interaction effect of component population density and variety had significant ($P<0.01$) effect on number of pods per plant. The maximum number of pods per plant 18.60 was recorded by 17.7% local common bean population density intercropped with 75% maize population density and the lowest 12.40 was recorded by 53.3% local common bean population density intercropped with 100% maize population density (Table 10). The reason in low number of pods were, due to interspecific competition of crops, the number of effective branch that can give greater number of pods was decreased so that the number of pods per plant was ultimately decreased. This finding is in agreement with Demesew (2002); Wogayehu (2005) on maize/common bean intercropping reported that, number of pods per plant was significantly affected by common bean varieties and planting density. Adem (2006) on sorghum-cowpea found a significant difference on number of pod per plant due to planting density. Turk *et al.* (2003) confirmed that number of pods per plant was negatively related to plant density.

Table 10. Interaction effect of common bean variety and component density of maize and common bean on number of pods per plant of sole and intercropped common bean

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	16.47^{c}	17.77^{b}	17.30^{b}
Maize 100% + Nasir	14.87^{d}	16.20^{c}	12.50^{f}
Maize 75% + Local	18.60^{a}	14.00^{e}	16.27^{c}
Maize 100%+ Local	18.22^{a}	16.13^{c}	12.40^{f}
SEM (±)	0.25		
LSD $_{(0.05)}$	0.51		
CV (%)	4.90		
Intercropped vs Sole cropped			
Inter crop	15.89^{b}		
Sole crop	22.04^{a}		
SEM (±)	0.28		
LSD $_{(0.05)}$	0.58		
CV (%)	7.10		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Number of seeds per pod: ANOVA result indicated that the main effects of component density, variety and interaction of the main effects as well as cropping system had significant ($P<0.05$) effect on number of seeds per pod (Appendix-Table 2). The highest number of seeds per pod 6.20 was recorded by 53.3% local bean population density intercropped with 75% maize population density, and the minimum number of seed per pod 4.00 was recorded by 53.3% Nasir common bean density intercropped with 100% maize population density (Table 11). The difference in number of seeds per pod might be because of inherent characteristics of the varieties and due to the population density of the plant. The same result was recorded by Yesuf (2003) on sorghum-haricot bean and Adem (2006) on sorghum-cowpea intercropping found significant difference was seen as a result of planting density effect. This showed that the highest number of seed per pod was recorded by sole crop and the minimum is recorded by intercropping.

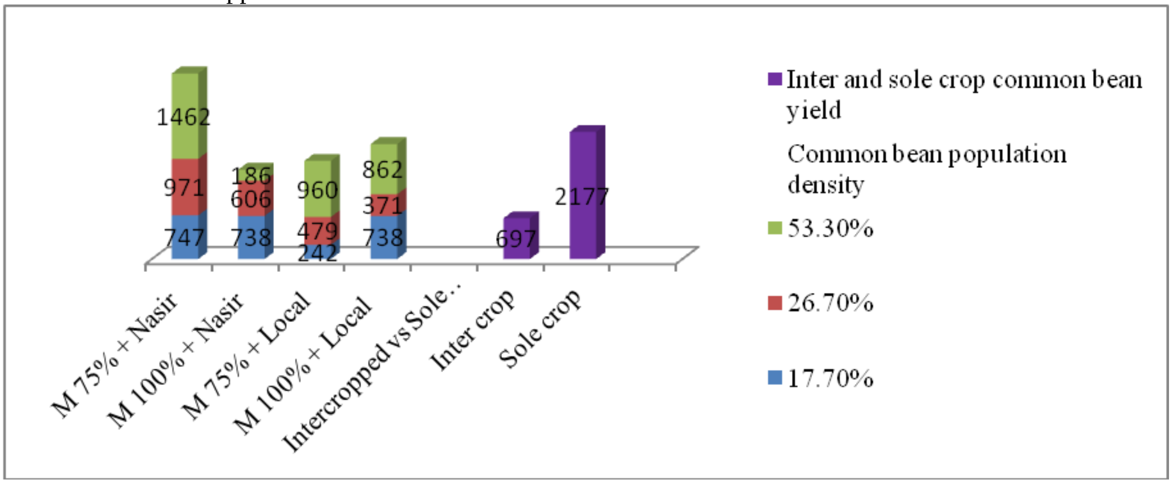
Table11. Interaction effect of common bean variety and component density of maize and common bean on number of seed per pod of sole and intercropped common bean

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	5.4c[e]	5.07[d]	4.67[e]
Maize 100% + Nasir	5.00[d]	6.00[a]	4.00[f]
Maize 75% + Local	5.07[d]	5.67[b]	6.20[a]
Maize 100%+ Local	5.67[b]	5.33[c]	5.87[b]
SEM (±)	0.11		
LSD $_{(0.05)}$	0.24		
CV (%)	2.6		
Intercropped vs Sole cropped			
Inter crop	5.33[b]		
Sole crop	6.25[a]		
SEM (±)	0.11		
LSD $_{(0.05)}$	0.22		
CV (%)	2.4		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Grain yield: Results revealed that grain yield was significantly (P<0.01) affected by the interaction effect of component plant population and variety as well as cropping system. The main effects also showed significant variation on grain yield. Among intercrops the maximum grain yield (1462 kg/ha) was, recorded for 53.3% Nasir common bean population density intercropped with 75% maize population density. The minimum grain yield (186 kg/ha) was, recorded for 53.3% Nasir common bean population density intercropped with 100% maize population density (Figure 2). The high population of the bean and maize component crops per unit area of land might cause crops to compute with each other for growth resources like nutrient and light that leads to decrease yield of crops. Similarly, Kheroar and Patra (2013) revealed that yield of intercrops were reduced by intercropping with maize that caused due to receipt of lower amount of solar radiation. Also the result was in agreement with Rezaei-Chianeh *et al.* (2011) showed that, the effects of maize densities and the interactions of maize and faba bean densities on grain yield of faba bean was significant. There was a general reduction in the yield of faba bean under intercropping system and also he said, the highest grain yield of faba bean was recorded in mono-cropping.

Figure2. Interaction effect of common bean variety and component density of maize and common bean on yield per hectare of sole and intercropped common bean.



Interaction of variety and component density
SEM (±) = 14.10
LSD $_{(0.05)}$ = 38.50
CV (%) = 8.30

Intercrop vs. sole crop
SEM (±) = 15.35
LSD $_{(0.05)}$ = 44.64
CV = 11.2

M= Maize, SEM= Standard Error of Mean, LSD = Least Significance Difference, CV = Coefficient of variation.

4. Conclusion

In this intercropping mixture of maize and common bean experiment: phonological, growth, yield and yield parameters as a whole were examined. With the exception of days to 50% emergency of common bean, all phonological parameters of maize and common bean did not affected by the main effects as well as the interaction effect of variety and population density. Result indicated that the main effect of common bean variety, component population density as well as interaction effect of the main effects showed a significant (P<0.05) difference on plant height, leaf area and leaf area index of common bean. Regardless of yield and yield components of maize, significant effects were observed due to common bean variety, component population density and interaction on seed number per cob, cobs per plant and yield per hectare of maize. Also in a similar case, concerning yield and yield components of common bean: number of pod per plant, number of seed per pod and yield per hectare showed statistically significant (P<0.05) difference due to the main effect of common bean variety and component density; also cropping system and interaction of the main effect showed significance difference. In general maize 100% population density intercropped with 26.7% population density of Nasir common bean variety, and as an alternative, maize with 75% population density intercropped with 53.3% population density of both varieties of common bean are recommended to make farmers benefited from the system.

Though selecting and practicing intercropping of best food crops varieties maximize yield of crops and maximize food security of the farmers. Mainly during off-season based on their agro-climatologic environment and performance, released new varieties and best local varieties should be evaluated and tested by farmers. In the present study, the selected maize variety (BHQPY-545) which was early maturity and best yielder and the intercropped bean varieties performed better in the area. So far, no research work had been made on the cropping system and proportion of maize and common bean productivity during off-season in the study area; so it needs further research on cultivars of maize and common bean intercropping combination that maximize production during off- season . As a final, it is difficult to conclude and give valuable recommendation in one year experiment at one site, hence further investigation on the selection of best compatible maize and common bean varieties and proportion of planting density should be studied.

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